MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

EOP 4076 – LASER TECHNOLOGY AND APPLICATIONS

(OPE)

7 MARCH 2017
2.30 p.m – 4.30 p.m
(2 Hours)

INSTRUCTION TO STUDENT

1. This Question paper consists of 7 pages including cover page with **4** Questions only.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) In preparing a research journal paper, you have to compare the empirical transverse mode profile for the TEM_{21} mode of your laser system with its theoretical model. Show how you derive the theoretical model of the mode distributions at the mirrors for the TEM_{21} mode in terms of the transverse variables x, y, $\rho = \sqrt{x^2 + y^2}$, and w (scaling constant).

[6 marks]

(b) In your experiment, you realized that direct pumping is not possible for your experimental laser system. Identify three possible situations that can prevent direct pumping from being an effective excitation process for the laser.

[6 marks]

(c) The upper laser level of the red He-Ne laser decays radiatively via ten transitions as shown in Figure Q1c (refer to page 3), including the well-known 632.8 nm laser transition. Compute the lifetime τ_u of the upper laser level of the laser.

[5 marks]

Continued...

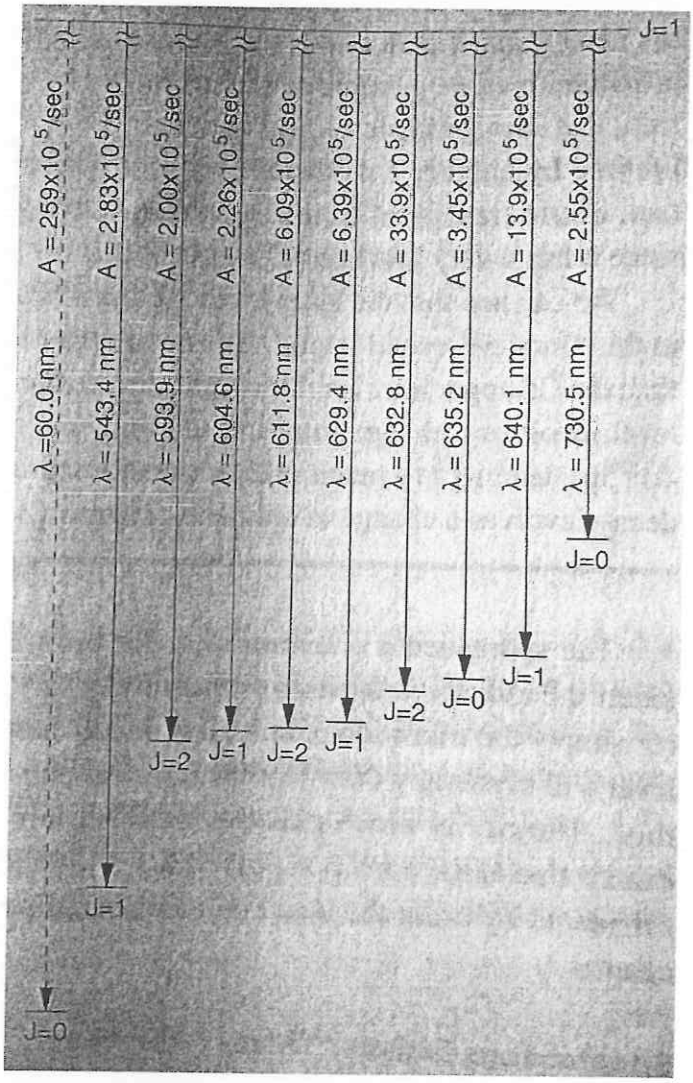

Figure Q1c: Radiative transitions of He-Ne laser.

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Question 2

(a) While leading a project on development of a dye laser, you discovered the presence of the triplet manifold. Explain to your teammates the consequences of this undesirable triplet manifold.

[6 marks]

(b) With the aid of a suitable diagram, design a mode-locking mechanism that is based on the *pump beam aperturing* effect, for use in a Titanium Sapphire laser, and explain its working principle.

[7 marks]

(c) In your laboratory, you are provided with a Helium-Neon (He-Ne) laser to produce mode-locked pulses. The He-Ne laser is operating at 632.8 nm with a mirror cavity spacing of d = 0.5 m. You know that the index of refraction of a He-Ne gas is approximately 1 ($n \cong 1$), and you measured the FWHM emission linewidth at the operating laser wavelength to be 1.5 x 10^9 Hz. Evaluate the mode-locked pulse width, Δt_p and the separation between pulses, Δt_{sep} that you can obtain from this mode-locked laser.

[6 marks]

(d) A Rh6G organic dye laser operating at 580 nm is end pumped (with an Argon ion laser at 488 nm) in a thin jet stream gain region of 0.5 mm thickness to produce a single-pass gain of 10%. The laser is operated in a cavity with two mirrors, one with 100% reflectivity, and the other with 95% reflectivity, and no other scattering losses exist within the cavity.

Assume that part of the population in the singlet upper laser level decays to the triplet T_1 state. The triplet absorption cross section at the laser wavelength and the peak pump absorption cross section at 488 nm has the same value of 3.8×10^{-20} m^2. The stimulated emission cross section at the laser wavelength is 2.5×10^{-20} m^2. Determine the population density in the triplet state that would just begin to stop the laser from operating.

[6 marks]

Continued...

Question 3

(a) You are trying to educate the laser welding workers in your company on the importance of operating below the boiling temperature of the materials to be welded. Explain to them the power loss problem associated with material vaporization during a laser welding process.

[4 marks]

(b) Your company provides surface hardening of ferrous material (4% carbon steel) using high power lasers. A client company requested for the deepest possible *case depth* for their material. How can you achieve this?

[5 marks]

(c) Most industrial laser cutters employ a gas stream coaxial with the laser beam. A junior engineer in your company proposed to use reactive gas for all materials, even for non-metallic materials. Compose a brief email to educate the junior engineer about the circumstances in which reactive and inert gas stream are preferable, respectively.

[6 marks]

(d) Evaluate whether CO_2 laser is suitable to cut brass, copper and aluminium, and justify your decision.

[5 marks]

(e) The maximum depth D of a hole that may be drilled by a laser pulse of energy E_0 is dependent on the heat capacity per unit volume c, the vaporization temperature T_B, the ambient temperature T_0, the latent heat of vaporization per unit mass L, the density ρ, and the area to which the beam is delivered A. Evaluate how many laser pulses are needed to drill through a 10 mm thick aluminium, if given that $T_B - T_0 = 2447\ ^\circ C$, $\rho = 2.7\ \text{gm} \cdot \text{cm}^{-3}$, $c = 0.97\ \text{J} \cdot \text{gm}^{-1}\text{deg}^{-1}$, and $L = 10{,}900\ \text{J} \cdot \text{gm}^{-1}$. The laser produces a pulse with an energy of 10 J, and focused to a spot with and area of $10^{-3}\ \text{cm}^2$.

[5 marks]

Continued...

Question 4

(a) On a product preview day at your company, you are introducing a laser system that exploits light diffraction to measure the flatness or waviness of a surface. Prepare a brief explanation in laymen terms on the procedure and working principle of your product.

[6 marks]

(b) (i) Measurements of the dimensions of a small object can be achieved with high accuracy through observations of the diffraction pattern formed when a laser beam is diffracted around the edges of the object. Discuss the effects of the object movement to the measurement using this method.

[4 marks]

(ii) During measurement of a wire diameter utilizing a laser with a wavelength of 0.81 μm, you observed the first spot from the direction of the laser beam was at an angle of 15 degrees. Evaluate the diameter of the wire.

[4 marks]

(c) Particle size distribution can be measured by using a laser. Justify why this approach is better than other technologies. In contrast, discuss the limitation on the measurable particle size.

[6 marks]

(d) (i) Design a fibre optic gyroscope (FOG) based on interferometer configuration, and describe the working principle of your design.

[7 marks]

(ii) Consider a fibre optic gyro with a radius of 10 cm that uses a light-emitting diode (LED) with a wavelength of 633 nm. Calculate the difference, Δ in frequency between the two propagating beams for a rotation rate, ω of 0.1 rad/hr.

[6 marks]

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Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

End of paper